POPULATION ESTIMATION OF MAMMALS: VALIDATION OF THE RESULTS FROM LARGE MAMMAL CENSUS AND LONG-TERM STUDY FROM RAJIV GANDHI NATIONAL PARK (NAGARHOLE NP)

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Population estimates of mammals provide considerable insights for conservation strategies, but only a few systematic population studies and annual census operations have given some direction to this effort. Even in these attempts, the methods adopted for estimating numbers vary substantially, and are usually not coupled with efforts to validate the results obtained, e.g., results of 1997 annual mammal census operation of Rajiv Gandhi National Park, southern India. The methods adopted for these operations were similar to each other. Hence, the census data of 1997 were reanalyzed using updated versions of data processing protocols. The overall results indicate that density estimates of all the species during the census using block counts were an underestimation, while line transect estimates were overestimates for several species. It is suggested that well-planned census operations, with focused training programmes and involvement of experts, may provide reasonably acceptable estimates.

Key words: population estimation, line transect method, block count, large mammals

INTRODUCTION

Estimating population density of animal species, paticularly mammals that attract conservation interest (Krishnan 1972; Ramachandran *et al.* 1986), is an important tool for their conservation and population management (Varman 1988; Karanth and Sunquist 1992; Varman and Sukumar 1995; Sutherland 1997). However, estimating animal numbers in a tropical forest habitat is difficult mainly because of poor visibility and relatively low density of some species resulting in inadequate sample sizes, for obtaining statistically precise results (Koster and Hart 1980; Varman and Sukumar 1995). Importantly, no systematic or scientific approaches have been followed to estimate population densities, except in one or two locations (covering about 2.5-4% of the distribution area). For example, the Asian Elephant *Elephas maximus* is distributed in 25,500 sq. km (Sukumar *et al.* 2006) of habitat in southern India, but only in one or two places, covering about 2.5-4% of its distribution area, have systematic or vigorous population estimations of the species been carried out (Karanth and Sunquist 1992; Varman and Sukumar 1995).

Population numbers that are available for species such as the Asian Elephant originate only from census programs. So far, systematic census programs have been initiated only for the Asian elephant, and since its inception, in 2002, three favourable census operations have been conducted (AERCC 2002, 2006; ANCF 2007). Though these census operations are assumed to be successful, their results are neither validated nor have they been compared with other long-term population studies on the species.

Comparison of results of long-term study with that of census programs is not possible for all species as they focus on one or two charismatic species; also, the methods adopted are substantially different. Long-term population studies (Karanth and Sunquist 1992; Varman and Sukumar 1995) follow the line transect direct method (Burnham *et al.* 1980; Buckland *et al.* 1993) of density estimates, while census programs depend on a combination of randomised block counts, direct or indirect line transect methods and waterhole counts (AERCC 2002, 2006; ANCF 2007). The most rigorous comparison of methods originate from the census program carried out at Rajiv Gandhi National Park in 1997, where both the line transect direct method and randomised block counts were followed to estimate the population densities of mammals (Varma and Venkataraman 1998). This is also a region where rigorous application of the line transect direct method was made by Karanth and Sunquist (1992) to estimate densities of similar taxa.

Although, since 2002 there has been substantial interest in estimation of mammal population numbers, no comparable effort towards validating census results has been made. Due to the absence of long-term studies on population estimates, and the fact that methods adopted by long-term studies and census operations are largely different, it was decided that the results of the 1997 census be reanalysed with updated versions of data processing protocols. The aim was to estimate population densities for large mammals through both randomised block count and line transect methods. The goal also was to compare the results obtained through either block or line transect methods or from a long-term study, and identify the advantages and disadvantages of using either

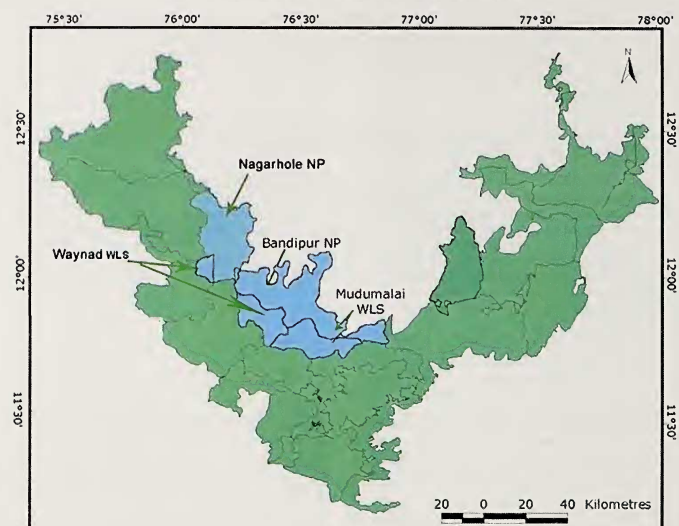

Fig. 1: Rajiv Gandhi National Park and adjoining forest divisions among different elephant divisions in Elephant Reserve Number 7

block or line transect methods or both. It is believed that this validation of the census results would act as a benchmark, particularly in taking a decision on choice of methods for future census operations.

MATERIAL AND METHODS

Study area and mammals

The Rajiv Gandhi National Park (formerly known as Nagarhole NP) is located between 11° 50'-12° 15' N and 76° 0'-76° 15' E, adjoining Bandipur National Park in Karnataka and Waynad Wildlife Sanctuary in Kerala (Fig. 1). The terrain of the Park is undulating with small hills and the average elevation is around 800 m above msl with the highest point occurring at Masal *betta* (950 m above msl). The major water sources for the Park are the rivers Lakshmanatirtha, Sarati Hole and Nagarhole, and there are also a number of other perennial and seasonal streams. The annual rainfall declines from west to east, from 1,500 to 900 mm; most of the rainfall occurs between June and September.

The vegetation type (Fig. 2) of the Park is dominated by mixed deciduous forests. The other forest types found in this area are dry deciduous, moist deciduous, semi-evergreen and scrub. Apart from these forest types, microhabitats such as swampy grasslands are also found. The Park has man-made forests, with Teak *Tectona grandis* and Eucalyptus *Eucalyptus* sp. plantations; an extensive teak plantation covering 9,000 ha was raised before the area was notified. Lantana *Lantana camara* and Eupatorium *Chromolaena odoratum* are proliferating in the Park.

The mammals considered for the long-term study and census operation were Spotted Deer *Axis axis*, Sambar *Cervus unicolor*, Indian Muntjac *Muntiacus muntjak*, Asian Elephant *Elephas maximus*, Gaur *Bos gaurus*, Hanuman Langur

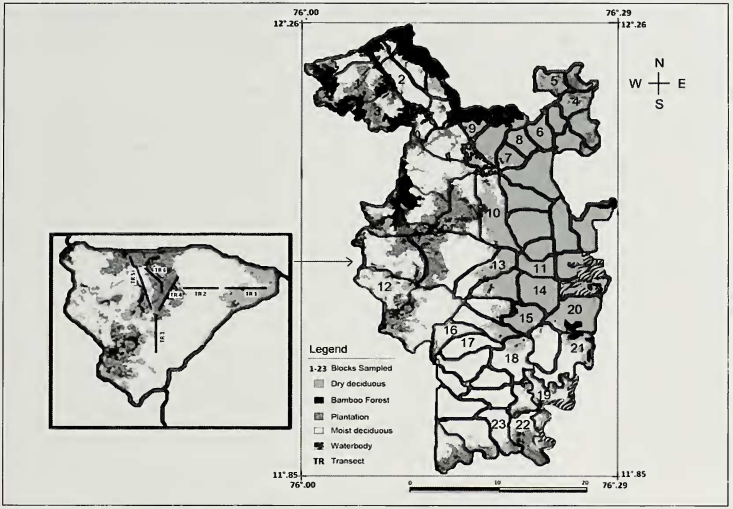

Fig. 2: Rajiv Gandhi National Park with vegetation types, blocks sampled and the location of transect lines used for the census operation

Semnopithecus entellus, Wild Pig *Sus scrofa* and Indian Giant Squirrel *Ratufa indica*. Common and scientific names used for these mammals are based on Menon (2003).

METHODS

Block count

A randomized block count method (Fig. 2) was used during the 1997 census. A total of 24 blocks (compartments) were chosen (from a total of 62 blocks identified for the Park) with the expectation that this would represent three different vegetation types, i.e., dry deciduous, moist deciduous and teak plantations. A total of 15 blocks for dry deciduous forest, 5 for moist deciduous forest and 4 for the teak plantation were chosen; the total sampled area covered was 295 sq. km. This constituted 151 sq. km in dry deciduous forest, 55 sq. km in moist deciduous forest and 89 sq. km in teak plantation. A total of 23 field parties walked in their respective blocks from 6:00 hrs to 18:00 hrs covering as much area as possible and counting the animals sighted. For each sighting, the number of animals seen, their age and sex class were noted.

Line transect method

Permanent transect lines of 2-4 km (Fig. 2), which were laid in different habitats by Karanth and Sunquist (1992), were used during the survey. The total distance walked during this period was 252 km. Each transect was covered once from 7:00-9:30 hrs and once from 16:00-18:30 hrs. For each animal sighted, the perpendicular distance from the centre of the group to the transect line was recorded, in addition to details of age, sex and group composition.

Data processing

Block count

The area for each block and vegetation type was calculated by digitising vegetation and forest compartment (blocks) maps. The block map was superimposed on the vegetation map. The dominant vegetation type in each block was noted and its area added to the total area of that vegetation type. Initially the areas of the blocks were calculated using GIS software IDRISI for Windows (version 1), and later it was updated through ERDAS 8.4 (LEICA Geosystems).

Densities of mammals in a sampled area were calculated by dividing the number of animals sighted in a given vegetation type by the total area of the vegetation type. The densities were also calculated separately for each vegetation type. The total density for a given species occurring in each vegetation type was calculated by multiplying the sampled area density in each vegetation type by the total area of that vegetation type in the Park. This gave the abundance of each species sighted during the census for each habitat type.

As the sample size obtained for each species was low for each vegetation type, no attempts were made to calculate the 95% confidence interval for the numbers estimated for each habitat. However, sightings for all the habitats were pooled, and the lower and upper limits of 95% confidence intervals were calculated for the total number of individuals estimated for each species for the entire Park. The variance for the number of individuals for each species for each block and area of each block was calculated using Choudhury (1991). The total number of individuals of each species was divided by the total area of the blocks sampled to obtain the population density of each species. The population density was multiplied by the total area of the Park to arrive at the total number of individuals for each species. The variance and standard error (SE) associated with the total number of individuals for each species was calculated to arrive at 95% confidence intervals of the total number estimated for each species (Choudhury 1991).

Line transect method

For the basic analysis, animal sightings were categorised into 10 m distance class intervals (from 0 to 100 m). The density of groups was arrived at using the program DISTANCE 5.0. To estimate animal density, the density of groups was multiplied by the mean group size. The standard error (SE) of the mean estimate was arrived at following Goodman (1960), and 1.96 SE was taken as the 95% confidence interval [see Varman and Sukumar (1995) for more details].

RESULTS

Block count

The density of Spotted Deer was highest in all three vegetation types, followed by elephants. In the three habitats put together a total of 705 elephants were estimated and the number of animals estimated for Spotted Deer, Hanuman Langur, Gaur, Sambar, Muntjac, and Indian Giant Squirrel was 1,162, 351, 169, 96, 59 and 41 respectively (Table 1).

Table 1: Number of sightings, density and abundance of large mammals through block count method for different vegetation types in Rajiv Gandhi National Park

Forest type	Sampled area	Total area	Species	Number of sightings	Number of animals	Density/sq. km for sampled area	Total number of animals for the total area
DDF	151	452	Indian Muntjac	11	15	0.1	42
			Asian Elephant	28	180	1.2	508
			Gaur	5	46	0.31	130
			Indian Giant Squirrel	8	8	0.05	22
			Hanuman Langur	13	106	0.7	299
			Spotted Deer	27	325	2.16	918
			Sambar	5	17	0.11	48
MDF	55	96	Indian Muntjac	8	9	0.16	15
			Asian Elephant	13	84	1.53	146
			Gaur	2	9	0.16	15
			Indian Giant Squirrel	6	8	0.15	14
			Hanuman Langur	4	30	0.55	52
			Spotted Deer	12	92	1.67	160
			Sambar	10	23	0.42	40
TP	89	128	Indian Muntjac	2	2	0.02	2
			Asian Elephant	6	36	0.4	51
			Gaur	5	17	0.19	24
			Indian Giant Squirrel	4	4	0.04	5
			Hanuman Langur	0	0	0	0
			Spotted Deer	13	59	0.66	84
	295	676	Sambar	4	6	0.07	8

DDF: Dry Deciduous Forest, MDF: Moist Deciduous Forest, TP: Teak Plantation

Table 2: Abundance of mammals estimated through block count method

S.no	Species	Density/sq. km	Estimated number of animals for the Park	LCL	UCL
1	Muntjac	0.1	70	59	81
2	Elephant	1.19	807	681	932
3	Gaur	0.35	239	202	277
4	Indian Giant Squirrel	0.06	40	34	47
5	Hanuman Langur	0.54	366	309	423
6	Spotted Deer	1.89	1281	1082	1480
7	Sambar	0.18	124	104	143

LCL: Lower Confidence Interval, UCL: Upper Confidence Interval

The density estimated for most of the species through this approach was low; however, the pattern clearly indicated their habitat usage pattern. Spotted Deer densities were highest followed by elephants in all the three habitats. Gaur densities were highest in the dry deciduous forest, followed by teak plantation and moist deciduous forest. Sambar utilised both teak plantation and moist deciduous forest equally (Table 1).

The results of population density and number for the Park, estimated using block count from all the three habitats, are presented in the Table 2. Even without any comparison, the number estimated by block count methods for different species of mammals were low, and for species such as Spotted Deer, Sambar, Gaur and Muntjac the density estimate by this method were substantially lower than expected.

Line transect method

The results of the line transect survey carried out during the census operation suggest that the number of sightings of Spotted Deer was greatest followed by Hanuman Langur, Indian Giant Squirrel and Elephant. However, the density estimated for Spotted Deer was the greatest followed by Hanuman Langur and Gaur. The number of sightings for both Sambar and Gaur was relatively low, but the density of Gaur was greater than the Indian Giant Squirrel. Sample size, mean group size, group density and individual density are given in Table 3. The overall pattern of the results of habitat usage by the line transect method was slightly different from that of the block count as density estimated for Spotted Deer by line transect method was highest followed by Hanuman Langur.

The comparison of the results of the block count versus line transect methods (Table 4) of census operations provide interesting insights. The density estimates of all the species by block count were an underestimation and line transect estimates appeared to be on the higher side for all the species (Table 3). The results of the differences across these methods were statistically significant (for all species $p < 0.001$, see Table 6 for z and p values).

To compare density results obtained from a long-term study of mammals (Karanth and Sunquist 1992), the distance covered, sample size, mean group size, group density and individual densities of mammals estimated by the long-term investigation are tabulated in Table 5. If the mean densities

Table 3: Sample size, mean group size, group density and individual density estimated for different species of mammals through line transect method

S.No	Species	Sample size	Mean Group size	SE	Group Density/km^2	SE	Individual Density/km^2	SE	95% CI		
									LCL	UCL	% CV
1	Indian Muntjac	38	1.19	0.12	3.95	1.05	4.7	1.34	2.08	7.32	28.43
2	Asian Elephant	56	6.54	0.87	1.82	0.38	11.92	2.95	6.14	17.7	24.73
3	Gaur	24	7.46	1.56	1.51	0.42	11.28	3.98	3.48	19.08	35.3
4	Indian Giant Squirrel	53	1.28	0.07	3.91	0.70	5.01	0.94	3.18	6.84	18.67
5	Hanuman Langur	66	7.08	0.67	2.49	0.43	17.64	3.47	10.84	24.43	19.66
6	Spotted deer	106	8.58	1.15	6.39	0.81	54.86	10.16	34.95	74.77	18.52
7	Sambar	29	2.17	0.21	1.64	0.41	3.55	0.95	1.69	5.42	26.74
8	Wild Pig	22	2.82	0.57	1.47	0.3	4.15	1.2	1.79	6.51	29.02

SE = Standard Error, LCL: Lower Confidence Interval, UCL: Upper Confidence Interval, %CV: Coefficient of Variation

Table 4: Density and total number estimated for block and line transect method during the census operation.

S. No	Species	Line transect		Block count	
		Mean Density/km^2	Total number	Mean Density/km^2	Total number
1	Indian Muntjac	04.7	3,050	0.1	70
2	Asian Elephant	11.92	7,736	1.19	807
3	Gaur	11.28	7,321	0.35	239
4	Hanuman Langur	17.64	11,448	0.54	366
5	Spotted Deer	54.86	35,604	1.89	1,281
6	Sambar	03.55	2,304	0.18	124

estimated by the line transect method during the census and the long-term study (Karanth and Sunquist 1992) are subjected to a statistical test for their significance, then the results will be as follows. Mean densities of Spotted Deer, sambar, gaur and muntjac were not statistically significant (see Table 6 for z and p values). There were clear differences for mean density estimates of elephant ($z = 1.98$, $p > 0.05$) and langur ($z = 3.1$, $p < 0.001$).

The comparison of the results of the block count and long-term study by the line transect method show that for elephants, the differences of densities' estimates across these two methods were not statistically significant ($z = 1.73$, $p > 0.05$), but for all other species the differences were highly significant ($p < 0.001$, see Table 6 for z and p values).

DISCUSSION

As seen from the results, for species such as Spotted Deer, Sambar, Gaur, and Muntjac, the block count method underestimates their number considerably. Without any information on the actual area of habitat used by different species of mammals, the density estimates cannot be extrapolated to the entire Park. If this is the situation, the total number projected by block count would be even lower, and clearly this is an underestimate for most species.

For species such as Sambar, Spotted Deer, Gaur and Muntjac, both long-term and short-term annual census based line transects could be an appropriate method for estimating their number. However, the estimated percentage of coefficient of variance (%CV) for most of the species during the census operation was high; the values were above 20% and ranged up to 35%. The values may be influenced by the sample sizes obtained for some of these species and more efforts are needed to increase these sample sizes. Increase in the sample sizes may decrease the %CV to an acceptable level (say = 15%) and this can be evident from the results of the line transects based on long-term population monitoring (see Tables 3 and 5 for sample size and %CV values).

For elephants, short-term or census-based line transect methods may not be an appropriate method. This could be due to their seasonal movement and this constraint may to some extent be applicable for the gaur too. For elephants, using census operation results (of line transect method), when the density was extrapolated to the entire area, the total number for the Park was about 7,736. The total elephant population estimated for 24 forest divisions in southern India is only about 9,950 elephants (Sukumar *et al.* 2006). Hence, the density estimated for the sampled area should not be extrapolated to the entire area. One of the reasons for the higher density estimate could be due to the number of sightings during the particular period of the census being very high. Karanth and Sunquist (1992) encountered 46 groups of elephants in a 462 km transect survey, whereas in the census operation, the number of groups sighted for the 250 km transect was 57. If the census operation was conducted in higher density areas or seasons, the density of elephants estimated for the survey would not be a true representation for the entire region or seasons.

Table 5: Sample size, mean group size, group density and individual density estimated for Rajiv Gandhi National Park by Karanth & Sunquist (1992)

S. no	Species	Sample size	Mean group	Group density	Individual density	95% CI		
						LCL	UCL	% CV
1	Muntjac	92	1.15	3.64	4.2	2.8	5.6	17
2	Elephant	56	3.59	0.92	3.3	1.9	4.7	22
3	Gaur	67	6.99	1.37	9.6	5.9	13.2	20
4	Langur	240	5.73	4.16	28.8	16.3	31.4	16
5	Spotted deer	376	6.27	8.08	50.6	38.5	62.7	12
6	Sambar	94	1.7	3.23	5.5	3.7	7.4	17

Density is expressed in sq. km, LCL: Lower Confidence Interval, UCL: Upper Confidence Interval, %CV: Coefficient of Variation

Table 6: Comparisons of the results of different methods of population estimation of large mammals by census and a long term study at Rajiv Gandhi National Park

	Block count	Line transect			Line transect	Long term study			Block count	Long term study		
Species	Mean density/km^2 (SE)	Mean density/km^2 (SE)	z value	p value	Mean density/km^2 (SE)	Mean density/km^2 (SE)	z value	p value	Mean density/km^2 (SE)	Mean density/km^2 (SE)	z value	p value
Muntjac	0.1 (0.01)	4.7 (1.34)	4.0	<0.001	4.7 (1.34)	4.2 (1.4)	0.2	> 0.05	0.1 (0.01)	4.2 (1.4)	3.5	<0.001
Elephant	1.19 (0.09)	11.92 (2.95)	6.2	<0.001	11.92 (2.95)	3.3 (1.4)	2.0	<0.001	1.19 (0.09)	3.3 (1.4)	1.7	> 0.05
Gaur	0.35 (0.03)	11.28 (3.98)	5.4	<0.001	11.28 (3.98)	9.6 (3.6)	0.2	> 0.05	0.35 (0.03)	9.6 (3.6)	4.8	<0.001
Langur	0.54 (0.04)	17.64 (3.47)	9.2	<0.001	17.64 (3.47)	28.8 (9.1)	3.1	<0.001	0.54 (0.04)	28.8 (9.1)	9.1	<0.001
Spotted deer	1.89 (0.15)	54.86 (10.16)	16.5	<0.001	54.86 (10.16)	50.6 (12.1)	0.2	> 0.05	1.89 (0.15)	50.6 (12.1)	13.9	<0.001
Sambar	0.18 (0.01)	3.55 (0.95)	3.4	<0.001	3.55 (0.95)	5.5 (1.9)	1.2	> 0.05	0.18 (0.01)	5.5 (1.9)	3.8	<0.001

The other reason for higher density estimates by census than by the line transect method could be due to the influence of mean group size. The mean group size estimated by Karanth and Sunquist (1992) for the elephant was 3.6, and the census estimate was 6.5. However, the group density estimate by Karanth and Sunquist (1992) was lower than that of the census operation. The higher group density and mean group size would have contributed to the higher density of elephants estimated by the census operation. Information connected to the deviation or error associated with mean group size was not available for the Karanth and Sunquist (1992) study and it was not possible to look at the statistical significance across the mean group sizes of these two approaches. Karanth and Sunquist (1992) estimated a density of 3.3 (95% CI: 1.9-4.7) and felt that the density may have been an overestimate and the actual density may be close to the lower confidence limit. This impression may match with the overall density estimate of the block count method of census operation.

Based on this experience, it can be concluded that for species that are alert, or shy in nature, active more during early morning or late evenings, small in size or found in low density, the block count method is not an appropriate method. For elephants, block count method could be an appropriate method. If a population estimate for elephants is to be made, it should be done through long-term line transect method while the block count method may provide reasonable estimates for census operation. Depending on the season of the operation, short-term transect method may over or underestimate the number of the species.

The major drawback of the census operation is that during the operation, particularly for the line transect method, the perpendicular distance measurements were arrived at based on visual estimations, and no range finder or other instruments were used. Distance measurements appeared to be more sensitive to error for elephant and arboreal species like Hanuman Langur. Fixing the geometrical centre of the group for distance measurements may be difficult for these two species and the absence of range finders may further complicate this issue. The services of untrained personnel and the absence of these instruments could have led to the underestimation of the sampled area and overestimation of the animal numbers.

It should be noted that long-term population studies cover only less than 1% of the total population size or geographical distribution area of most of the species and these investigations are restricted only to certain periods of time. Except for one investigation of long-term population monitoring of mammals in Mudumalai (CES 2007), no study has been carried out in more than three years. Therefore, the regular census programs may have some scope for understanding fluctuations in population numbers of most of the species. If census results are processed properly, they also have the advantage of providing details of the habitat utilisation patterns for most of the species.

The options available to the wildlife managers are to critically review the outcome of the earlier census operations and based on the findings improve the quality of future census programs. If these reviews disqualify census operations altogether, resource that have been earmarked for census operation only should be invested into long-term investigations as resource used for short-term census program can be meaningfully used for the long-term studies. With the given manpower and resource limitation, the census operation has shown results comparable with those of long-term study carried out in a region where the biomass of ungulate is very high (Karanth and Sunquist 1992). This may indicate two basic facts: well-planned census operations with trained personnel and the knowledge gained from the experts in the field may improve the quality of the results and provide reasonably acceptable numbers. More specifically, the outcome of the exercise (some of the results matching with long-term investigation) may be due to a chance factor and more rigorous evaluations have to be carried out for meaningful conclusions. The findings also suggest that future census operations should consider carrying out the exercise in regions where long-term population investigations are on and where the method adopted for both these approaches are compatible.

ACKNOWLEDGEMENTS

Census operation was carried out as a part of annual mammal census operation, and the Asian Elephant Research Conservation Centre, Bengaluru, provided the technical support for the program. Forest Department staff of the Rajiv Gandhi National Park has shown considerable interest in attending and participating in the training program and the census operation.

Our former colleague Dr. Arun Venkatraman provided valuable support while designing and executing the program. The census data was reanalysed with the support provided by Archana Prasad of Centre for Ecological Sciences, and Santanu Datta of the Asian Nature Conservation Foundation (ANCF) provided GIS support. Dr. Renee M. Borges and Dr. N.V. Joshi (Centre for Ecological Sciences) have gone through the earlier version of the document and were motivation for this publication.

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